1 Introduction

Rounding

The Mean

Standard Deviation

Five-Point Moving Average

CHAPTER ONE:
INTRODUCTION

Quality Control/Quality Assurance (QC/QA) is often used synonymously with the term Quality Assurance (QA). AASHTO defines Quality Assurance as "All those planned and systematic actions necessary to provide confidence that a product will perform satisfactorily in service." This definition considers QA to be an all encompassing concept which includes quality control (QC), acceptance, and independent assurance (IA). A better understanding of the QC/QA concept may be made if the characteristics of the specifications are considered. These include:

1) QC/QA recognizes the variation in materials and test methods.

2) QC/QA uses a statistical basis that is applied and modified with experience and sound engineering judgement.

3) QC/QA places primary responsibility on the Producer for production control.

The procedure used by INDOT in the past to accept aggregates required that a stockpile of aggregates be tested to verify compliance with specifications, and the stockpile subsequently approved or disapproved prior to shipment. This pass/fail specification became very confrontational with Producers when failing tests were obtained and shipments delayed or stopped to active contracts. Even when eventually resolved, project delays were inevitable in many cases. A QC/QA procedure whereby Producer's tests could be used for acceptance, and shipments of aggregates made on demand was needed. The Certified Aggregate Producer Program (CAPP) was introduced as the procedure to accomplish both needs.

The CAPP designates specific quantities of material to be tested, material test values, test equipment calibrations, and statistical concepts to be applied to control aggregate products. As such, a standard method for rounding values is required to be established and basic statistical rules be presented. This chapter discusses the procedures for rounding numbers, and the basic statistical calculations.

ROUNDING

When calculations are conducted, rounding is required to be in accordance with 109.01(a) using the standard "5" up procedure. There are two rules for rounding numbers:

1. When the first digit discarded is less than 5, the last digit retained should not be changed.

   Examples: 2.4 becomes 2
   2.43 becomes 2.4
   2.434 becomes 2.43
   2.4341 becomes 2.434

2. When the first digit discarded is 5 or greater, the last digit retained should be increased by one unit.

   Examples: 2.6 becomes 3
   2.56 becomes 2.6
   2.416 becomes 2.42
   2.4157 becomes 2.416

The Certified Aggregate Producer Program requires that test and statistical values be calculated to the nearest decimal place as indicated in Figure 1-1.

Property	Nearest Whole Unit (0)	First Decimal Place (0.0)	Second Decimal Place (0.00)	Third Decimal Place (0.000)
Crushed Particles	X			
Flat & Elongated	X			
Percent Compliance	X			
Control Limits*	X	X		
Absorption		X		
Decantation		X		
Deleterious		X		
Gradation		X		
Surface Moisture		X		
Target Mean		X		
5-Point Moving Ave.		X		
Fineness Modulus			X	
Standard Deviation			X	
Z Value			X	
Bulk Specific Gravity				X

* May be rounded to (0.0) or (0)

Figure 1-1. Decimal Places.

THE MEAN

The simple mathematical average of any group of numbers is the mean. In other words, the mean is the sum of all the measurement values divided by the number of measurements. The symbol for the mean is $\bar{x}$. As an example, the mean for five numbers would be calculated as follows:

$$\bar{x} = \frac{x_1 + x_2 + x_3 + x_4 + x_5}{5}$$

STANDARD DEVIATION

Whereas the mean is an average of all the data values, the standard deviation is an average value of the dispersion of data from the mean. Standard deviation is usually signified by a small s or the Greek letter Sigma (σ). For the CAP Program σ_{n-1} is used.

The procedure used to compute the standard deviation is to subtract the mean from each value, square this difference, sum, divide by one less than the number of values, and take the square root. These steps may be expressed in terms of a formula as follows:

$$\sigma_{n-1} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}}$$

where $\bar{x}$ is the arithmetic mean, n is the number of sample values and $\sum$ indicates the summation of all values.

Note that squaring the deviations from the mean removes the negative signs. Dividing by n - 1 gives us approximately an average squared deviation. Taking the square root puts the result back into the same units as the original values.

Example:

x_i	$x_i - \bar{x}$	$(x_i - \bar{x})^2$
14.3	1.7	2.89
11.2	-1.4	1.96
14.1	1.5	2.25
12.6	0.0	0.00
12.9	0.3	0.09
12.7	0.1	0.01
13.2	0.6	0.36
11.4	-1.2	1.44
12.3	-0.3	0.09
11.6	-1.0	1.00
126.3		10.09 (Sum of squared differences)

$n = 10$

$$\bar{x} = \frac{\sum x_i}{n} = 12.6$$

$$\sigma_{n-1} = \sqrt{\frac{\sum (x_i - \bar{x})^2}{n-1}} = \sqrt{\frac{10.09}{9}} = \sqrt{1.121} = 1.06$$

FIVE-POINT MOVING AVERAGE

The moving average is a useful tool for tracking trends of the mean. The CAPP requires that the moving average be the average of the most recent five data points.

For a moving average of five test values, the group of the first five measurements is averaged. When an additional test value is obtained, the first value is dropped, the sixth value is added, and the new group averaged. When a seventh value is obtained, the second value is dropped, and the new group averaged, and so on. An example of this procedure is as follows:

Data: 4.8, 5.3, 5.0, 4.7, 5.1, 5.5, 4.6

$$\text{First Average} = \frac{4.8 + 5.3 + 5.0 + 4.7 + 5.1}{5}$$

$$= \frac{24.9}{5} = 5.0$$

The first number, or 4.8, is dropped and the sixth value, or 5.5, is added and the second average is:

$$\text{Second Average} = \frac{5.3 + 5.0 + 4.7 + 5.1 + 5.5}{5}$$

$$= \frac{25.6}{5} = 5.1$$

Next, the 5.3 is dropped and 4.6 is added:

$$\text{Third Average} = \frac{5.0 + 4.7 + 5.1 + 5.5 + 4.6}{5}$$

$$= \frac{24.9}{5} = 5.0$$